Proton Decay at DUNE FD

$p \to K+ \bar{\nu}$

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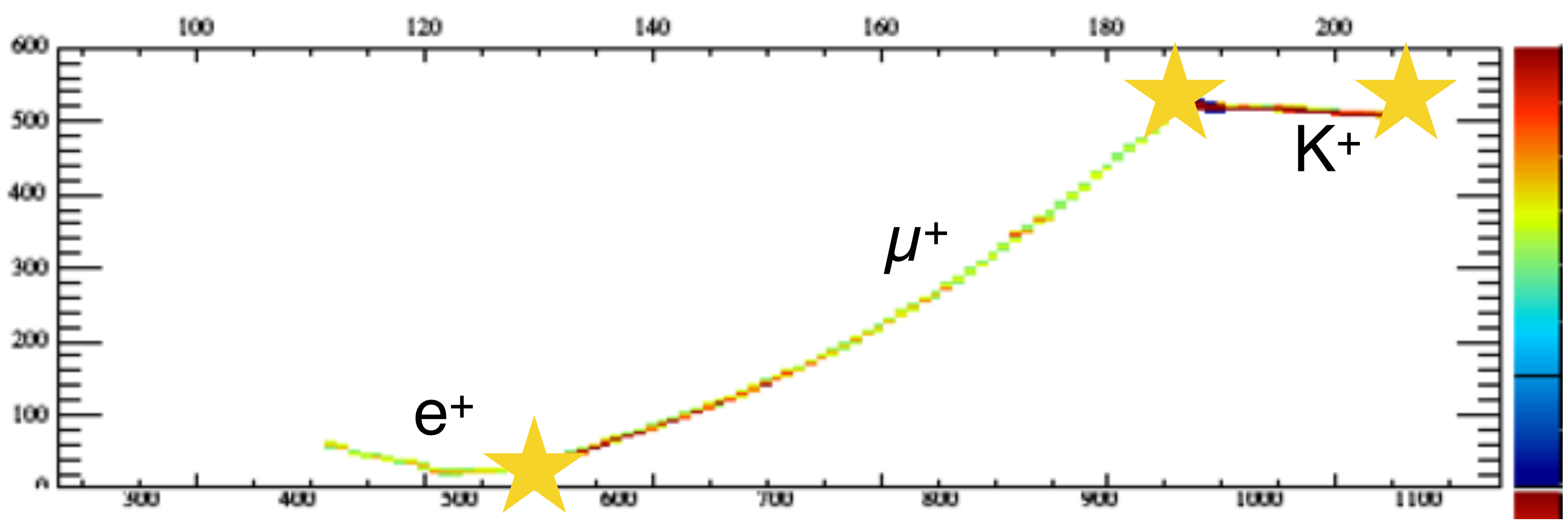
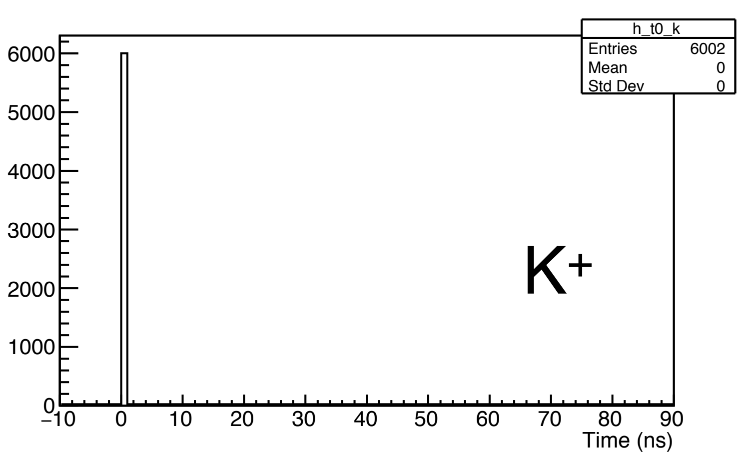
Content

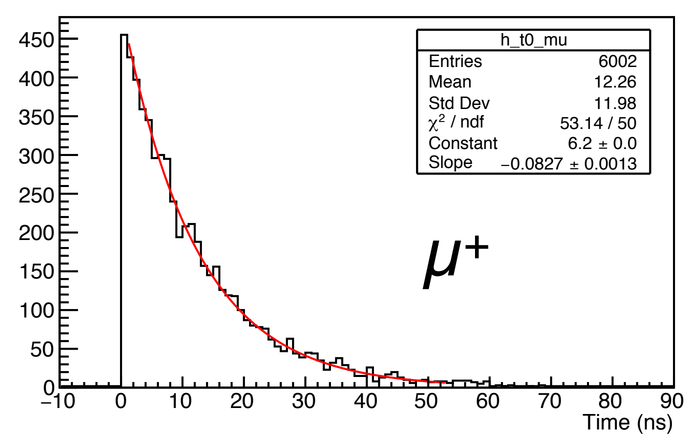
1)Photon Detector Info from Proton Decay Event
2)PID: Chi2 vs PIDA
3)Signal Efficiency and Background Rates

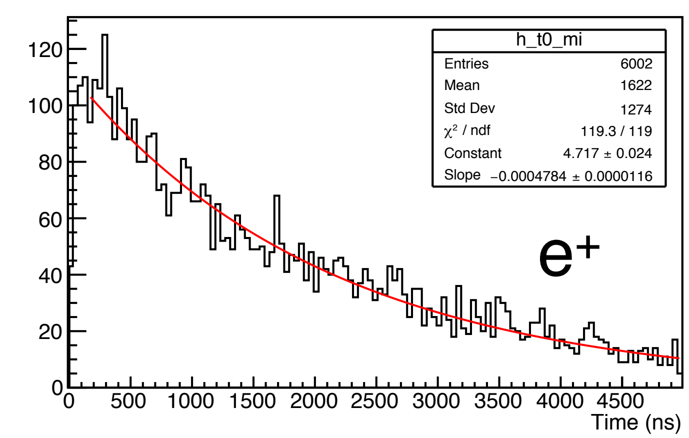
Proton Decay at DUNE FD, p → K+$\bar{\nu}$

Looking at PDS information









- Since the propagation of photons is much faster than the drifting of ions along the electric field light provides a references for a T0
- A PDS provides also a trigger system for non-beam events
- For a proton decay, k^+—>μ^+—>e^+ a perfect PDS would have 3 “flashes” i.e. one per each decay

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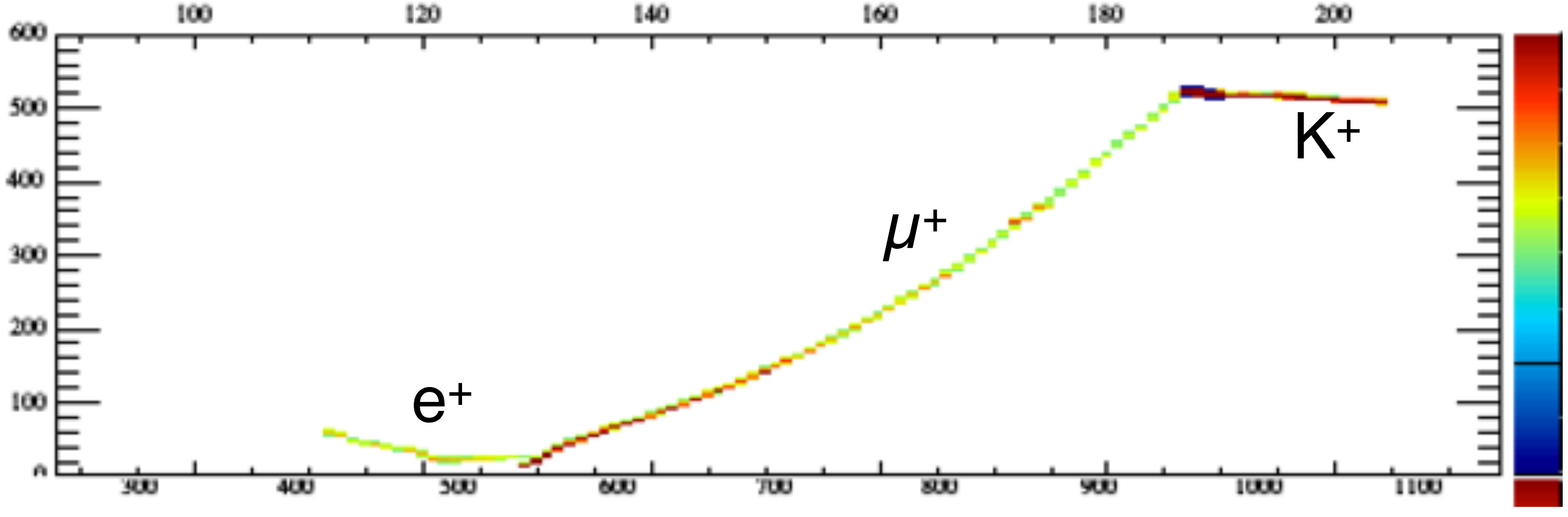
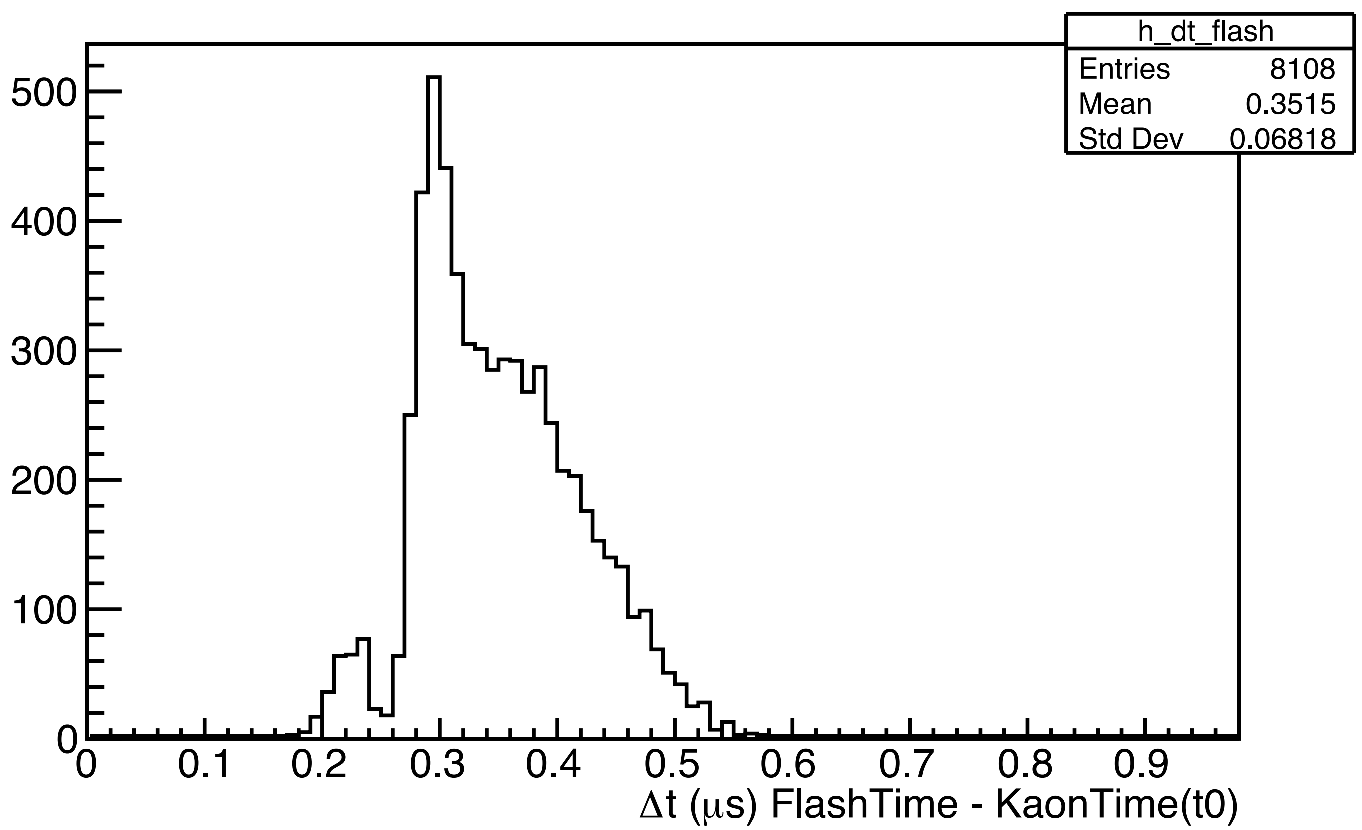
Looking at PDS information



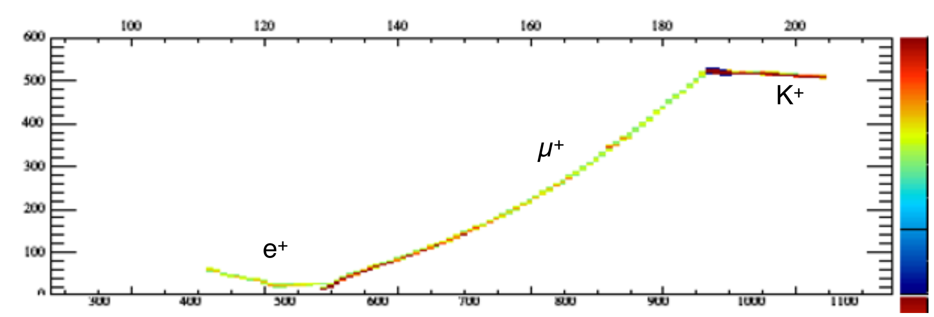
- In the current reconstruction we have high-level reconstruction for the PDS
- Optical flashes (OpFlashes) are a collection of optical hits (OpHits)
- OpFlash Alg finds clusters of OpHits in time
- How many flashes does reco find in a proton decay event?

Proton Decay at DUNE FD, p → K+$\bar{\nu}$

- Given the timing resolution of the PDS is very likely that OpHits from the kaon and muon OpHits would be reconstructed as a single flash
- So naively we expect two flashes K/μ flashes and a michel flash



- It seems that OpFlash Alg needs some tuning



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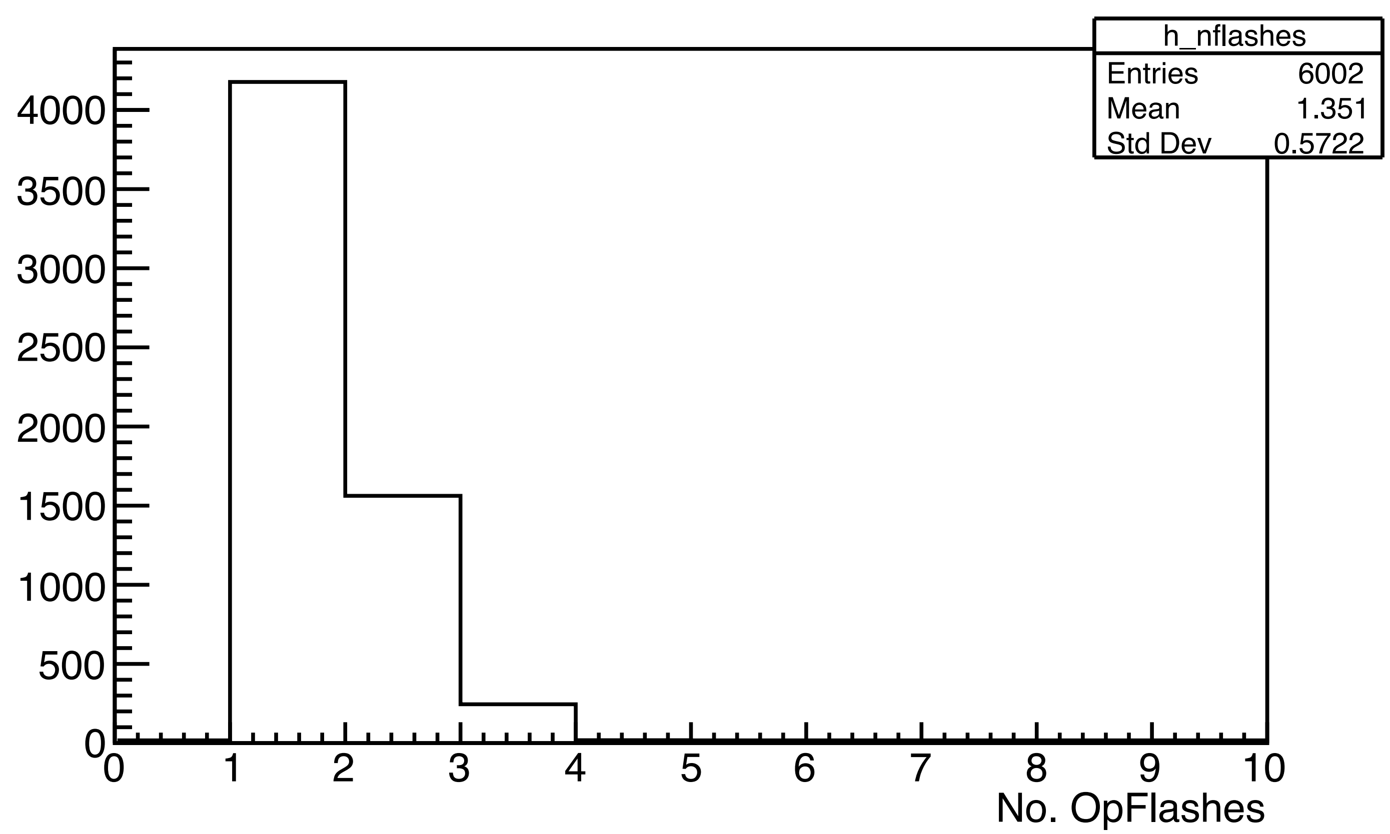

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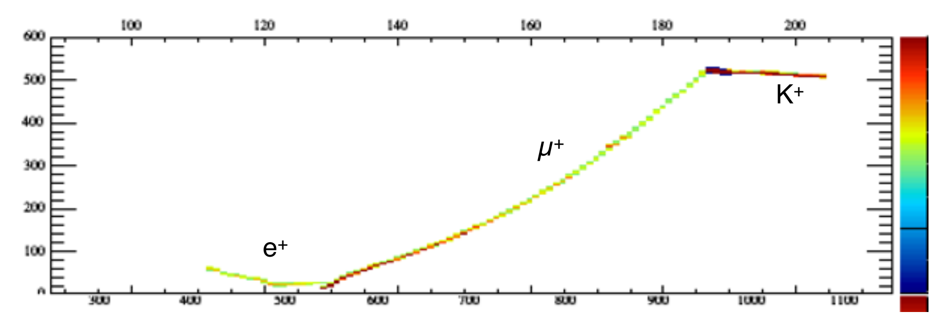
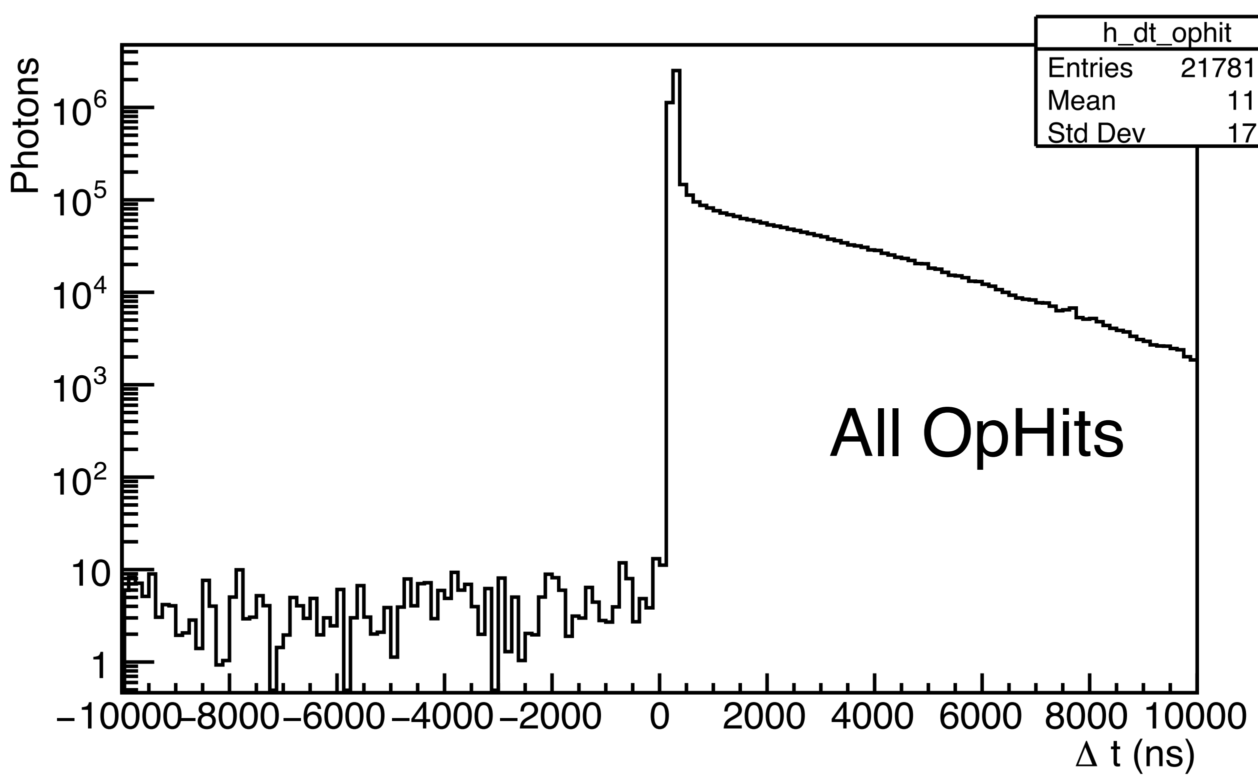
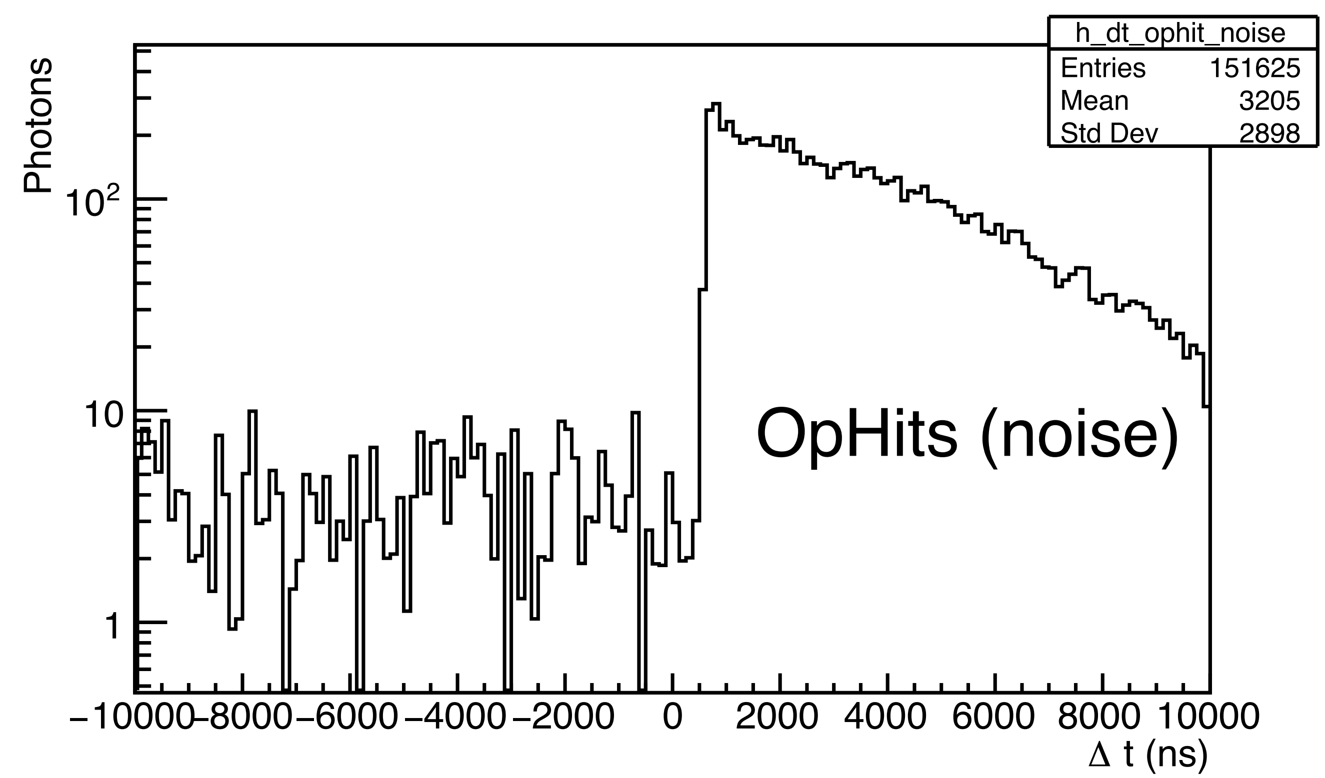


Proton Decay at DUNE FD, p → K+$\bar{\nu}$

- Optical flashes (OpFlashes) are a collection of optical hits (OpHits)
- Look at OpHits to see if we can optimize OpFlash reco for proton decay events
- Noise= An OpHit no associated with an MCParticle (Photonbacktracker)





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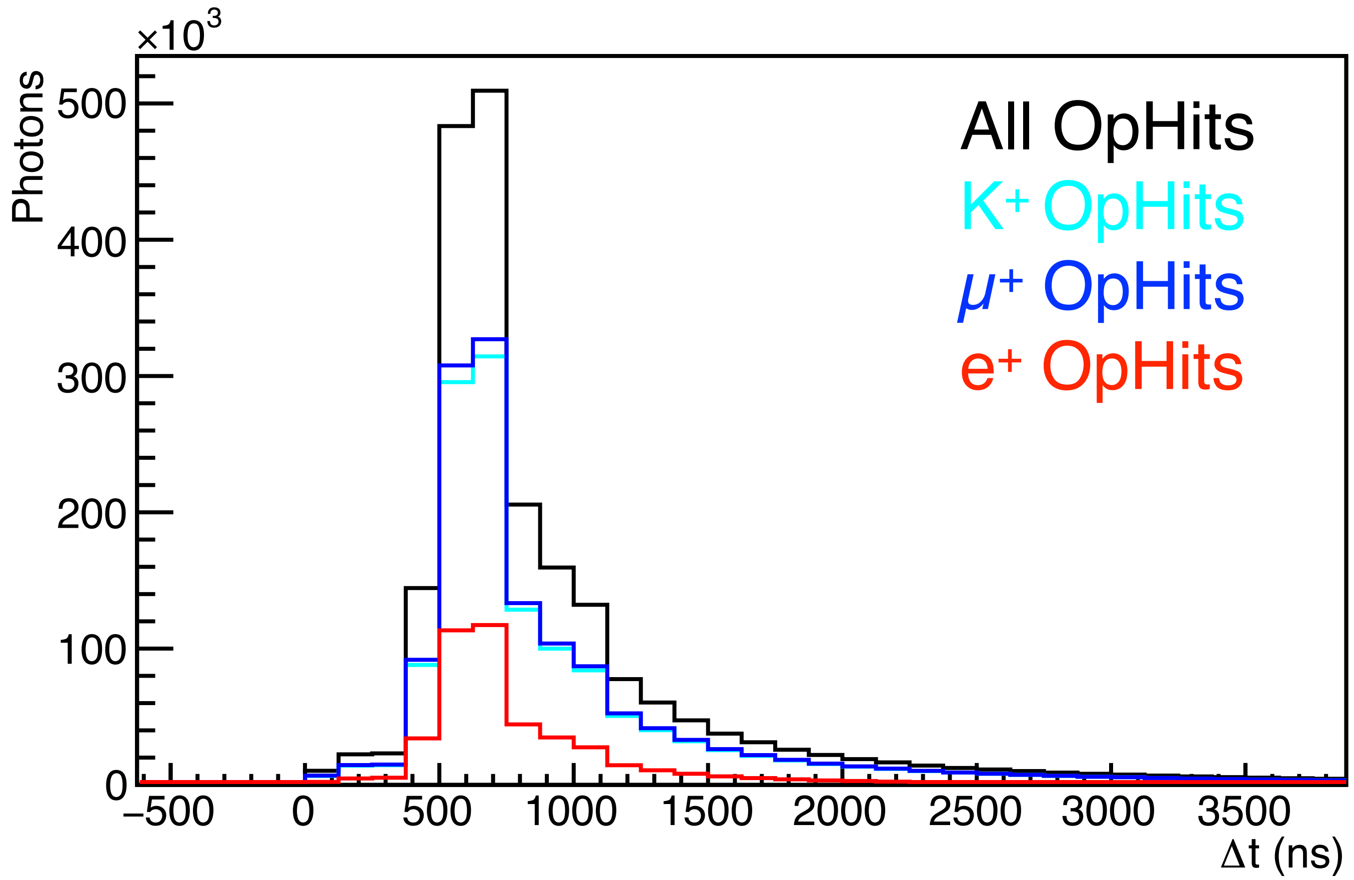

- The peak time seems the same for all OpHits, naively I will expect that the width of the OpHit to be deferent for each particle (kaon, muon, michel)
- Instead of using the peak time, calculate the start time as = peak time - width

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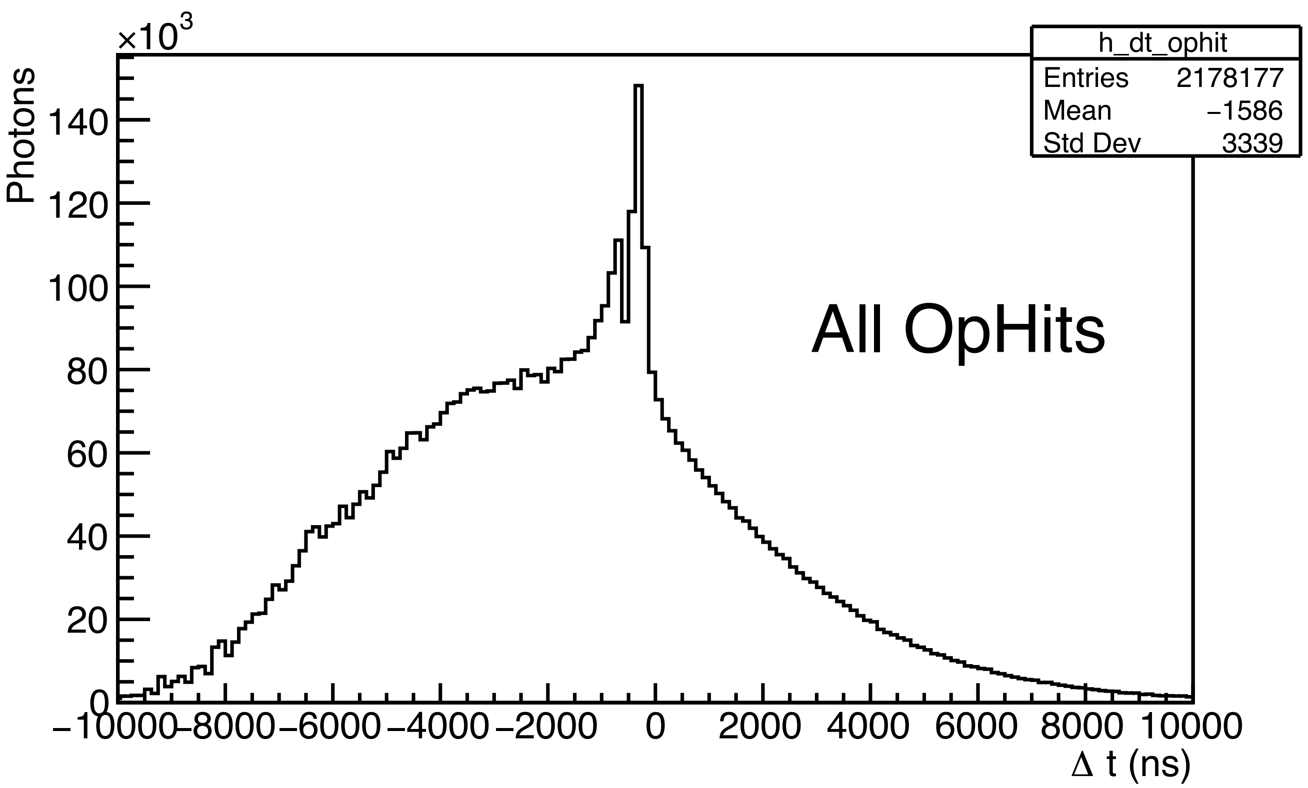
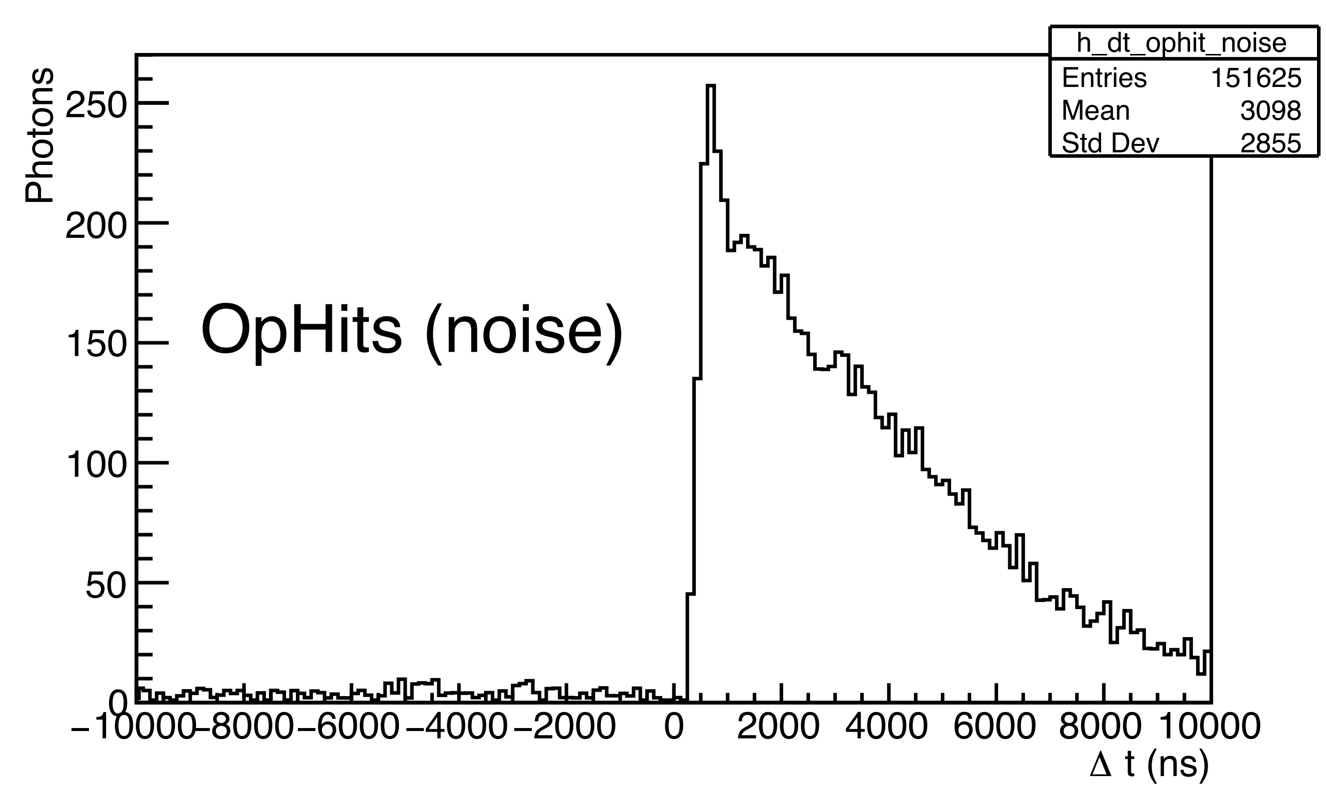
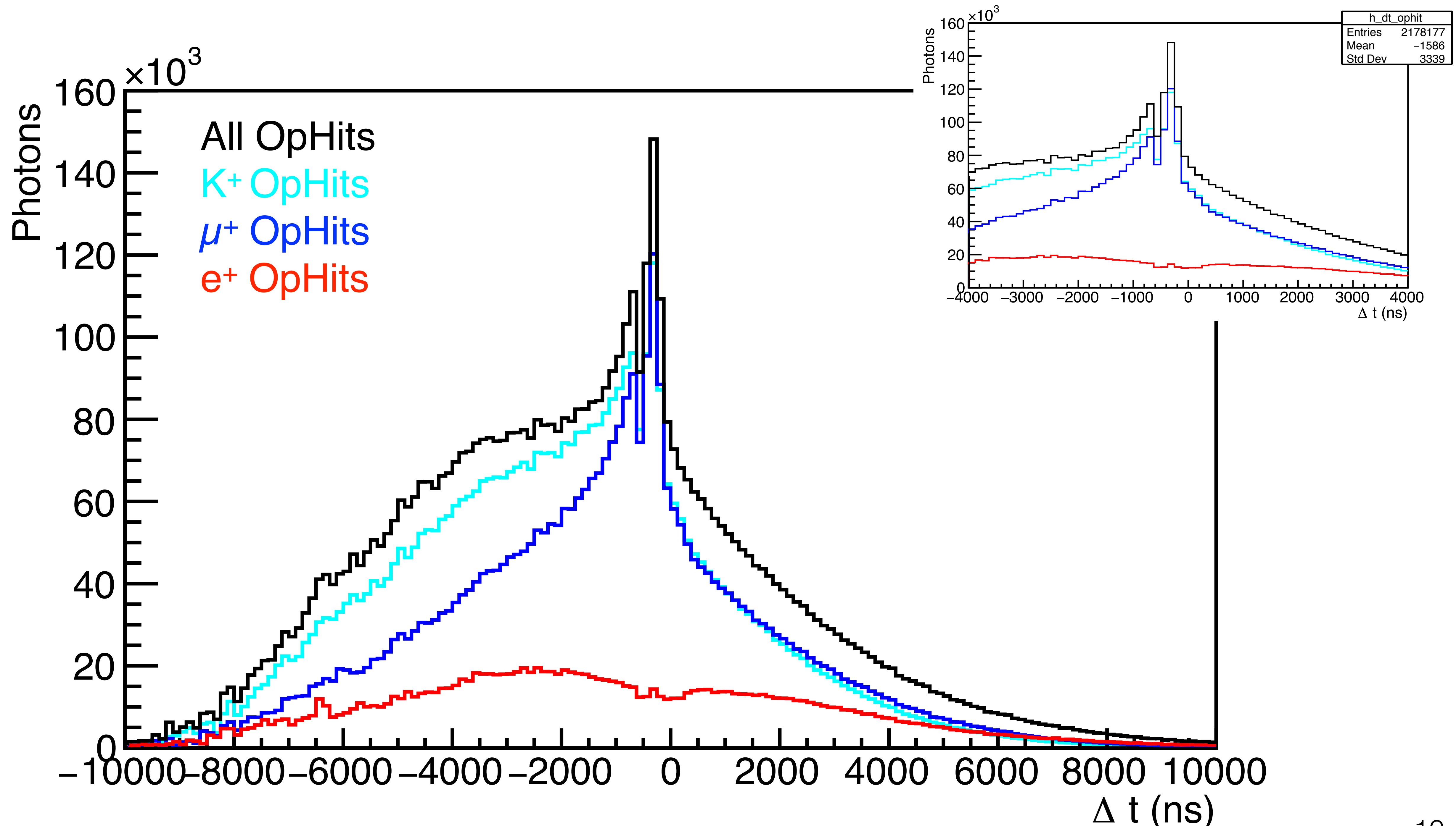




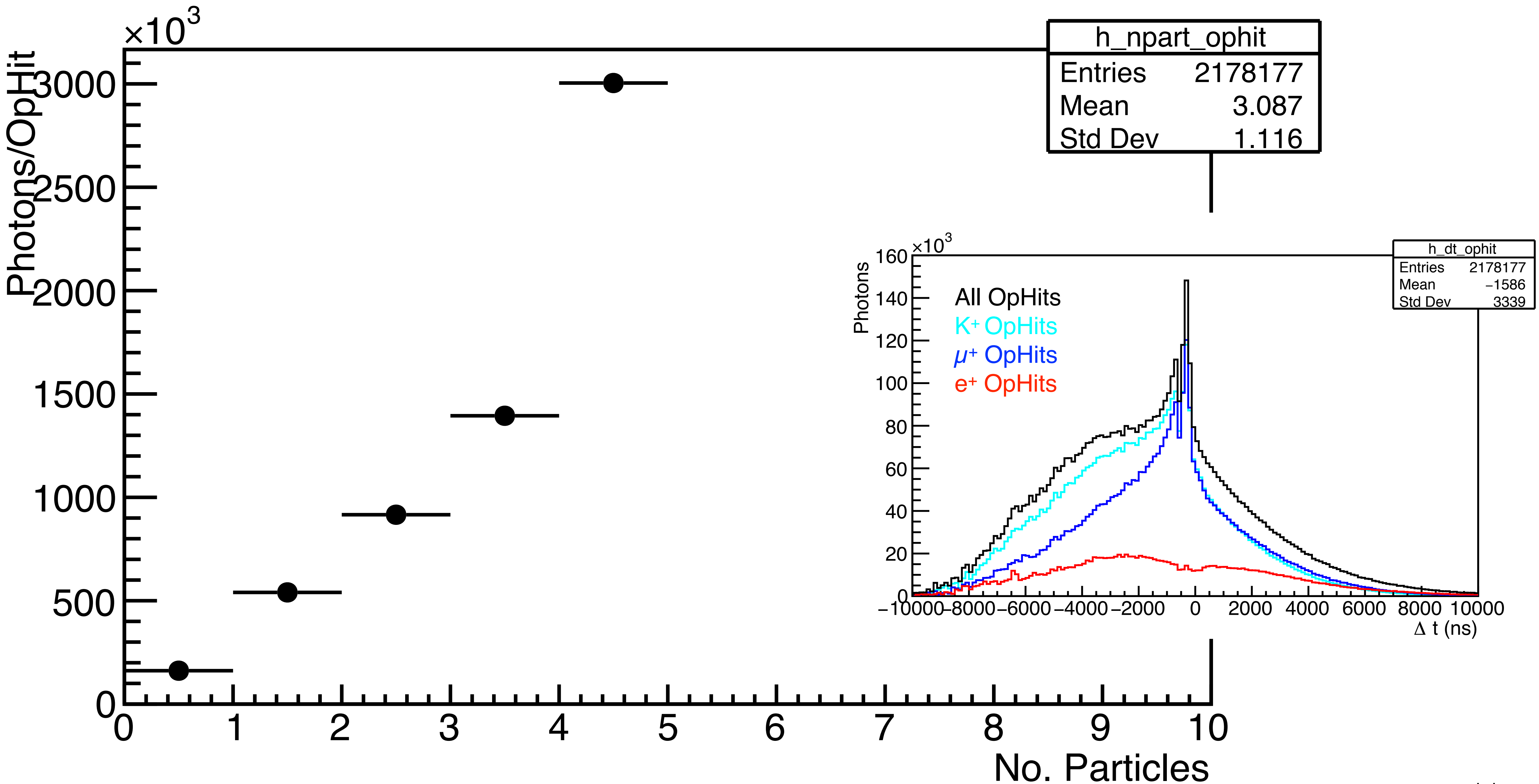
Proton Decay at DUNE FD, p → K+$\bar{\nu}$

- By using PhotonBackTracker find which MCParticle is associated to a OpHit



Proton Decay at DUNE FD, p → K+$\bar{\nu}$

- By using PhotonBackTracker find which MCParticle is associated to a OpHit
- Multiple particles are contribute to a single OpHit



Comments I

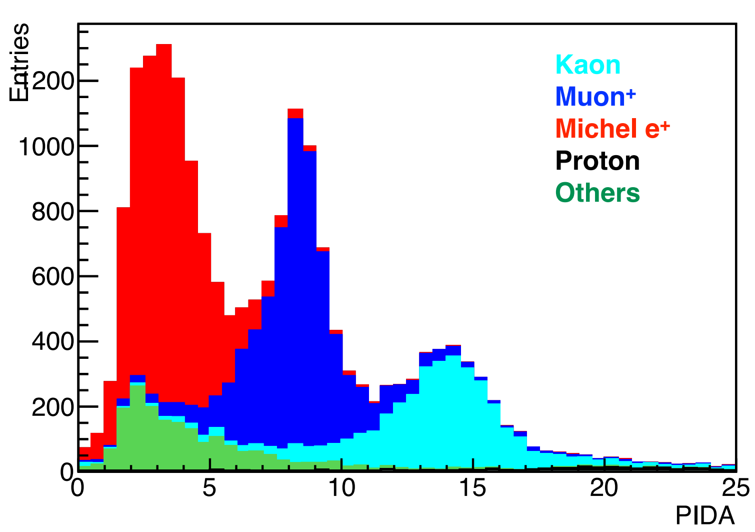
- The current PDS cannot discriminate decays (due to timing resolution and mechanism of scintillation in LAr)
- We have to go back one step and first demonstrate that we can reconstruct t0 i the presence of background i.e. Ar39 flash vs proton decay flash

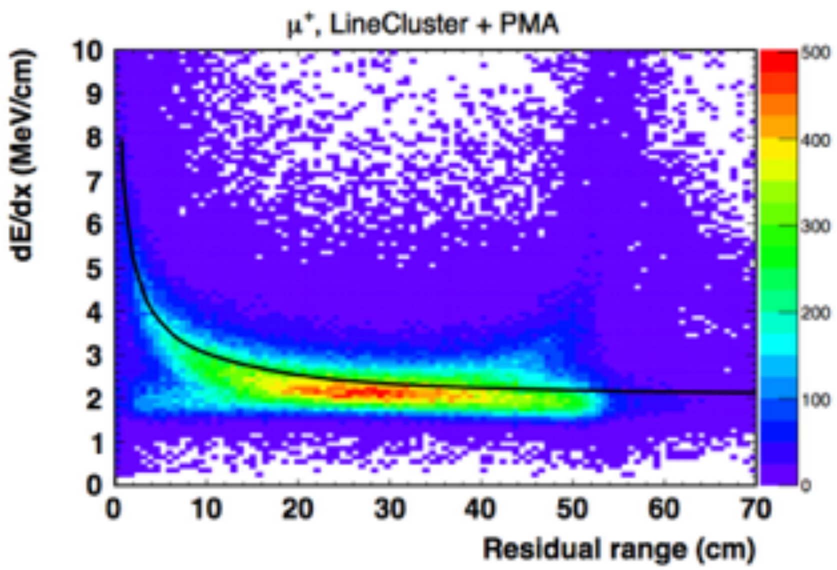
  To do:
    - Demonstrate that we can reconstruct interaction flash an it is inside of FV
    - Simulate Ar39 on top of kaons to see we can select the right flash from the kaon/muon/michel
- For the future… at some point we should combine TPC (hit) and PD (Ophit) to improve reconstruction
- We are using SIPMs no PMTs… sad!

PIDA vs Chi2 PID

Using linecluster	PIDA Eff (Purity)	X Eff (Purity)
Kaon	50.4% (91.2%)	42.9% (95.7%)
Muon	76.7% (98.9%)	56.0% (99.5%)

- Muons are often misID as pions
- Often there is more than one muon according to X^2 PID, michel track is reconstructed as a muon (MIP like), so in addition to require PID we need to look at track range





Signal Efficiency and Background Rates (Atm only)

	Signal Efficiency	Atm Background Efficiency
Kaon ID & stopping muon	38.0%	3.2%
No shower-like	30.5%	0.35%
Kaon primary vertex	23.2%	0.04%
40Kton/year		4 events

- Looking only at K—> μ events, very hard to add K—>π_s
- There are 3 key points for this analysis
  - Flash reco (vs Background)
  - Kaon ID (and muon)
  - No Shower-like
- We definitely can improve on reconstruction, thus we can improve on event selection and background rejection
- How much?

Signal Efficiency

Kaon ID & stopping muon	Signal Efficiency
Current	38.0%
Optimistic projection	85%
Conservative projection	60%

$$PID \otimes Trk\ Eff \otimes Det\ res$$

- We haven't achieved the full potential of the reconstruction, but no matter what we will have limited efficiency for low KE kaons

Kaon ID & stopping muon No shower-like	Signal Efficiency
*Current	30.5%
*Optimistic projection	80%
*Conservative projection	55%

- ν_e shower ID is crucial for DUNE so I expect that the reco/ID of shower event to be very efficient

*Cumulative efficiencies

Signal Efficiency and Background Rates

Kaon ID & stopping muon No shower-like	Signal Efficiency	Atm Background Rate (40kt/year)
Current	30.5%	4 events
Optimistic projection	80%	0 events
Conservative projection	55%	1 events

- There are 3 key points for this analysis
  - Flash reco (vs Background) ← Essential, haven't looked at
  - Kaon ID (and muon)
  - No Shower-like

Commets II

CDR selling points

1) Demonstration of efficiency improvement by a factor ~5x better than a Cherenkov detector
2) Quasi-free background search

From CDR to FDTF Report

- Given the current status of the reconstruction/selection, search for proton decay using LArTPC technology does improve the selection efficiency in comparison with a Cherenkov detector
- A quisi-free background search is feasible

Why CDR & FDTF number are so different?

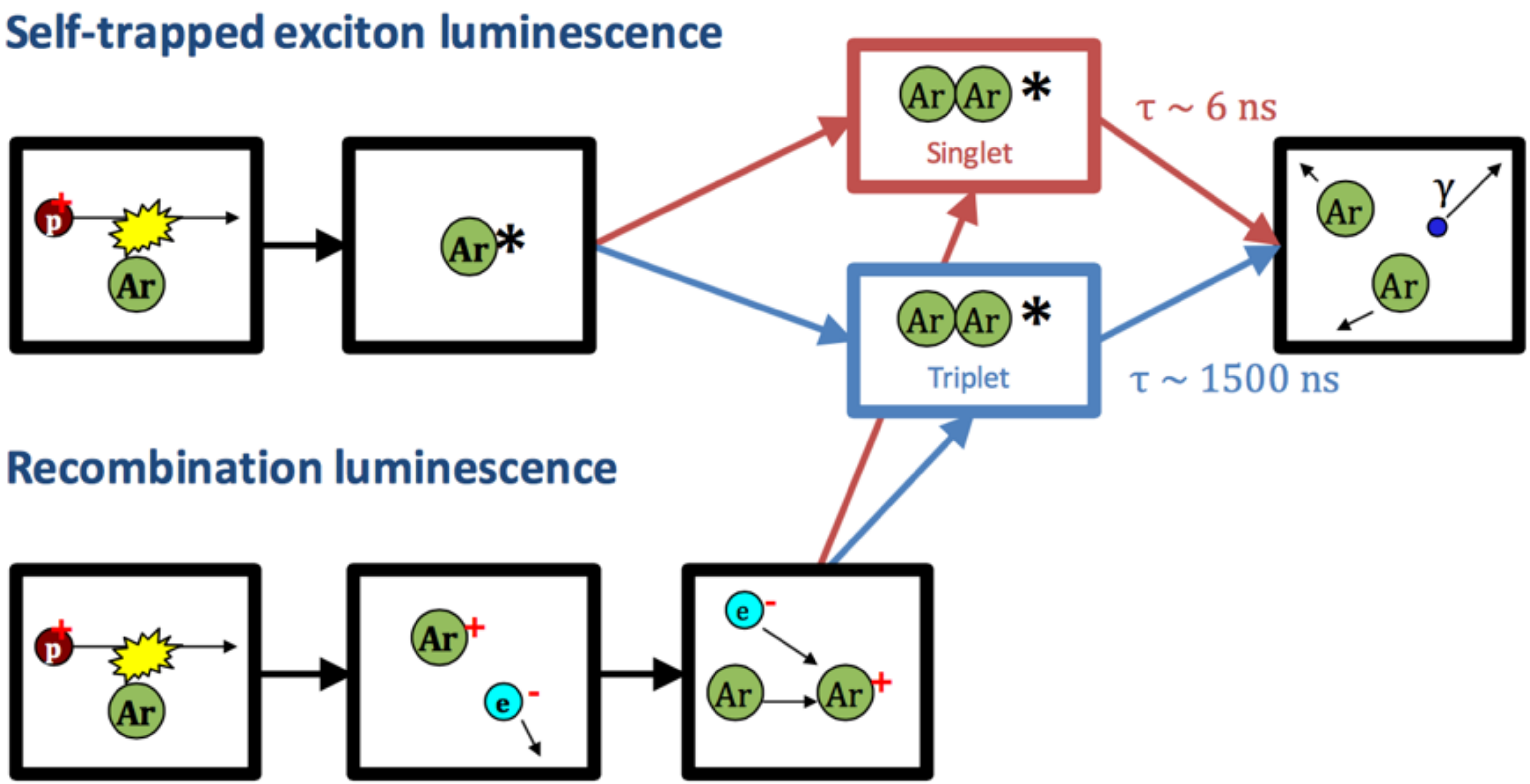
- CDR assumes 30 MeV/c momentum threshold ~1 MeV KE for Kaon ID (current tracking threshold is ~25 MeV)
- CDR assumes 99% Kaon ID eff
- CDR FSI model is quite different in comparison with the current GENIE FSI model
- etc…

The End

Extras

Alex Himmel

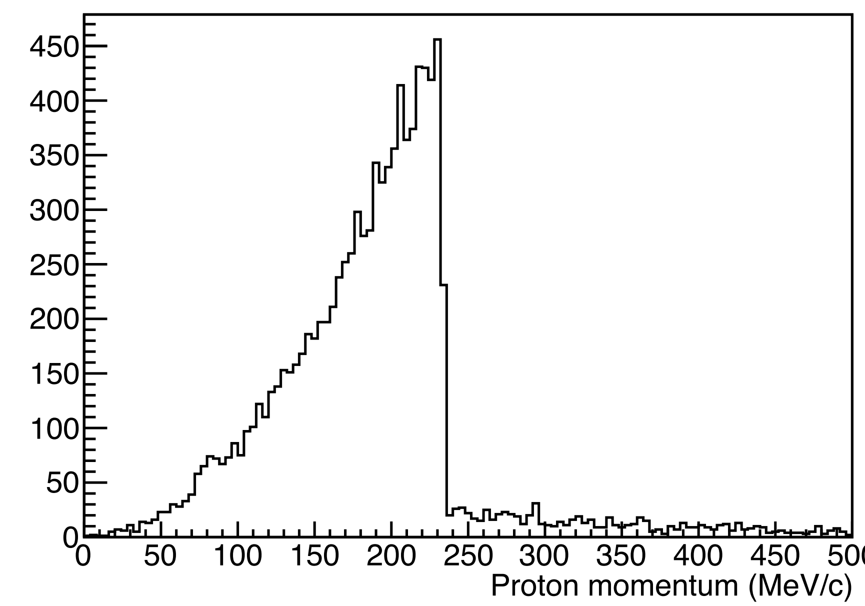
Mechanisms of Scintillation in Argon



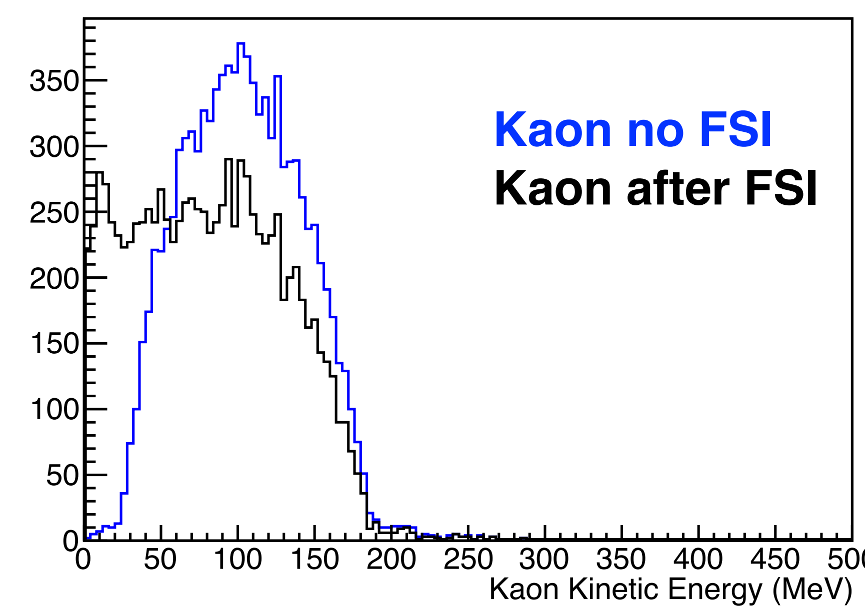
Proton Decay at DUNE FD, $p \rightarrow K^{+}\bar{\nu}$

How we simulate proton decay at DUNE?

- GENIE 2.12.2
  - Nuclear mode
    - ☑ RFG with short range nucleon-nucleon correlations
    - ☐ No binding energy
    - ☐ No de-excitation photon production for Ar, only for Oxygen (Cherenkov detectors)



  - Kaon-nucleus & GENIE FSI
    - ☑ FSI are simulated using "hA" model
    - ☑ No absorption
    - ☑ Elastic and Inelastic scattering
    - ☐ K^+ via π is not included
    - ☐ No K^+ charge exchange
    - ☐ GENIE FSI model never adds or removes K^+ from the final state



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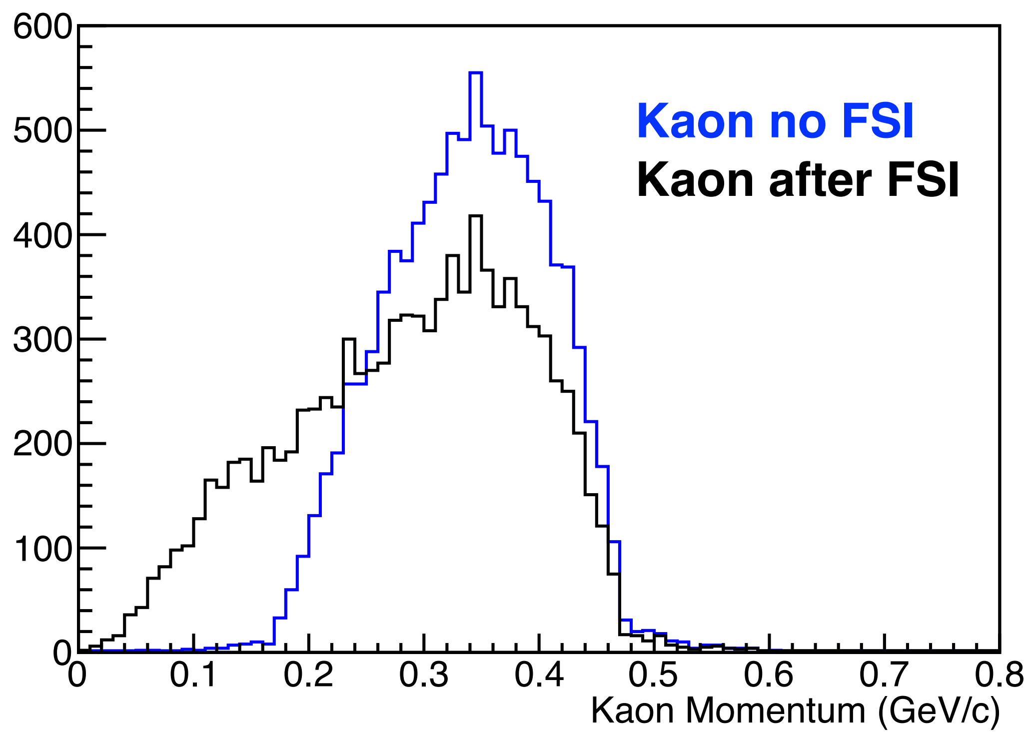
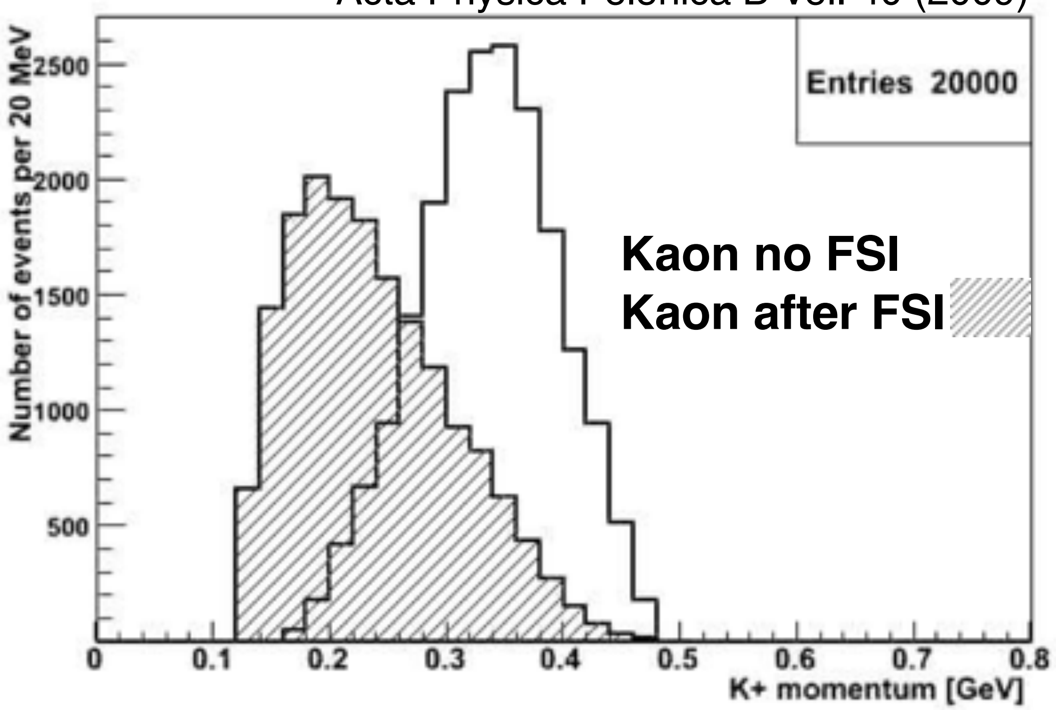


D. Stefan, Artur M. Ankowski
Acta Physica Polonica B Vol. 40 (2009)



- *Current simulation at the generation level seems to be different from the CDR studies*
- *Need to set systematic uncertainties on the signal because FSI model*

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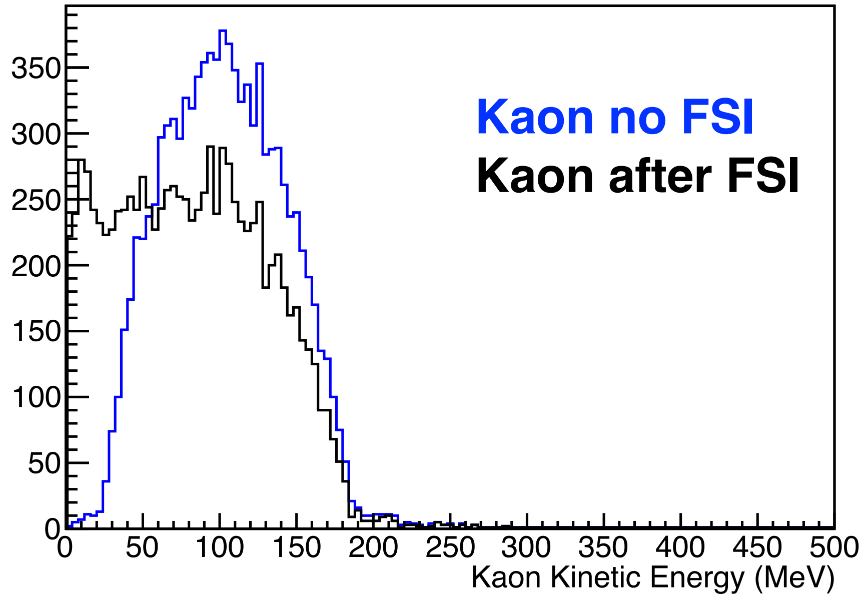

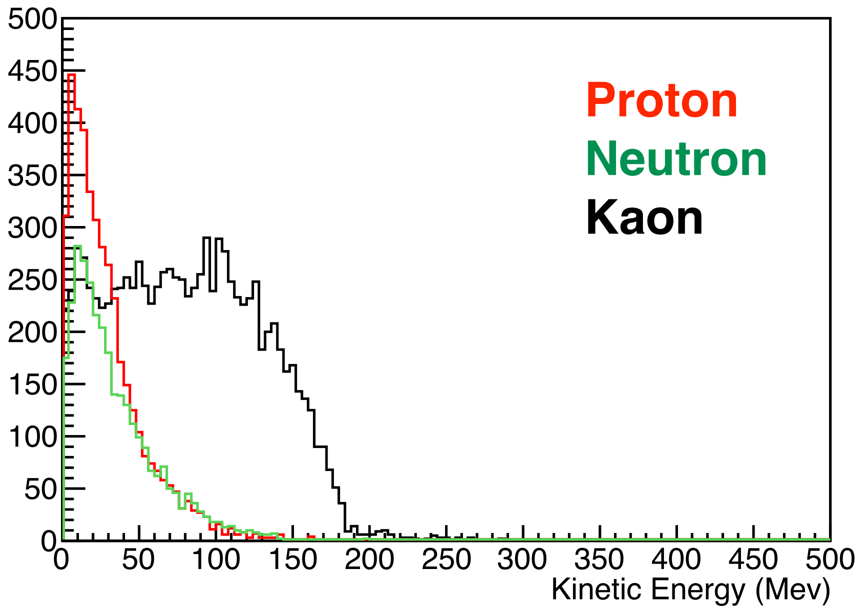

How far can travel a 5 MeV kaon?

Because FSI the kaon spectrum is pushed to lower KE values

Proton and neutrons appear because inelastic scattering and go from few MeVs up to a few hounders MeVs, this modifies the “elegant topology”

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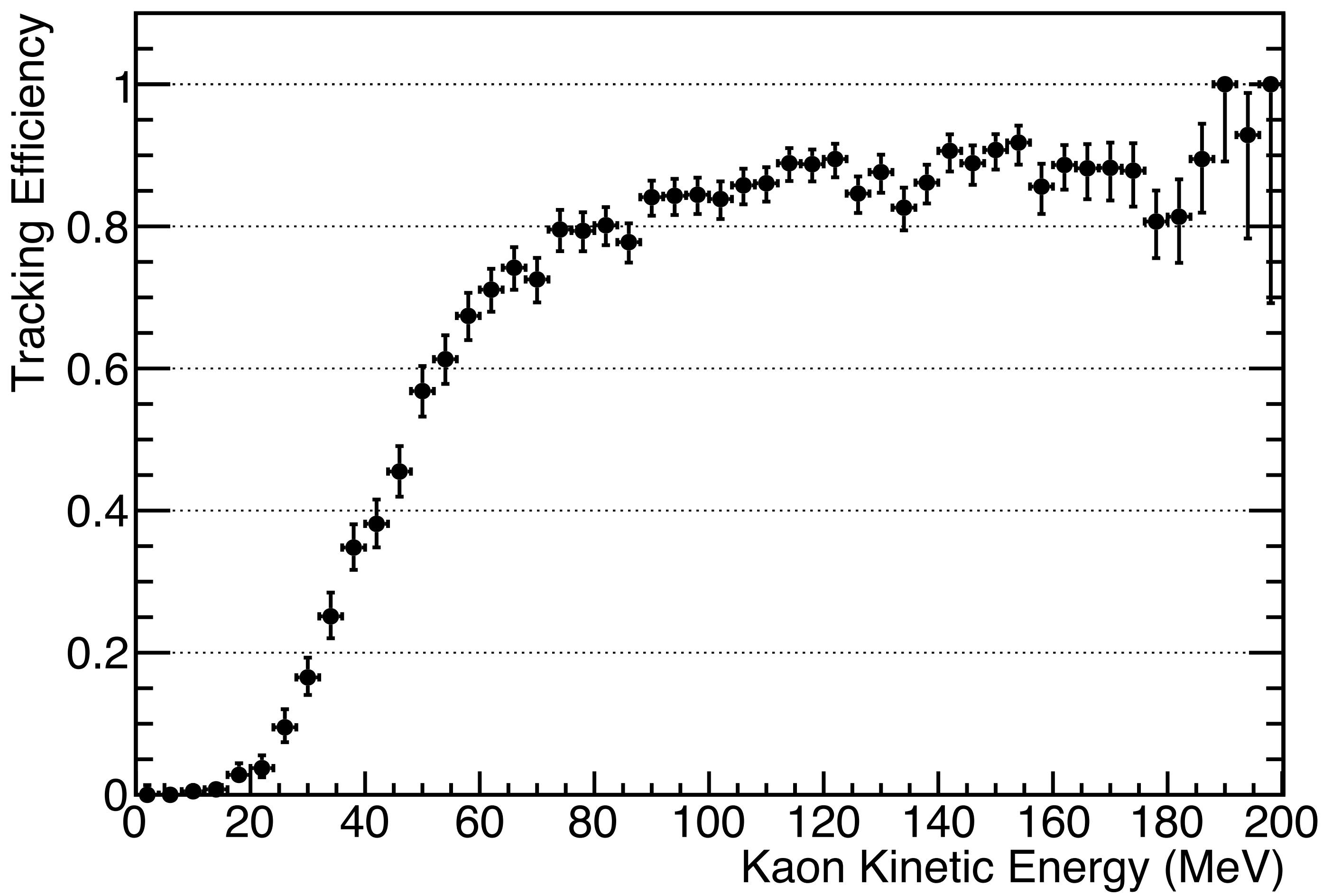


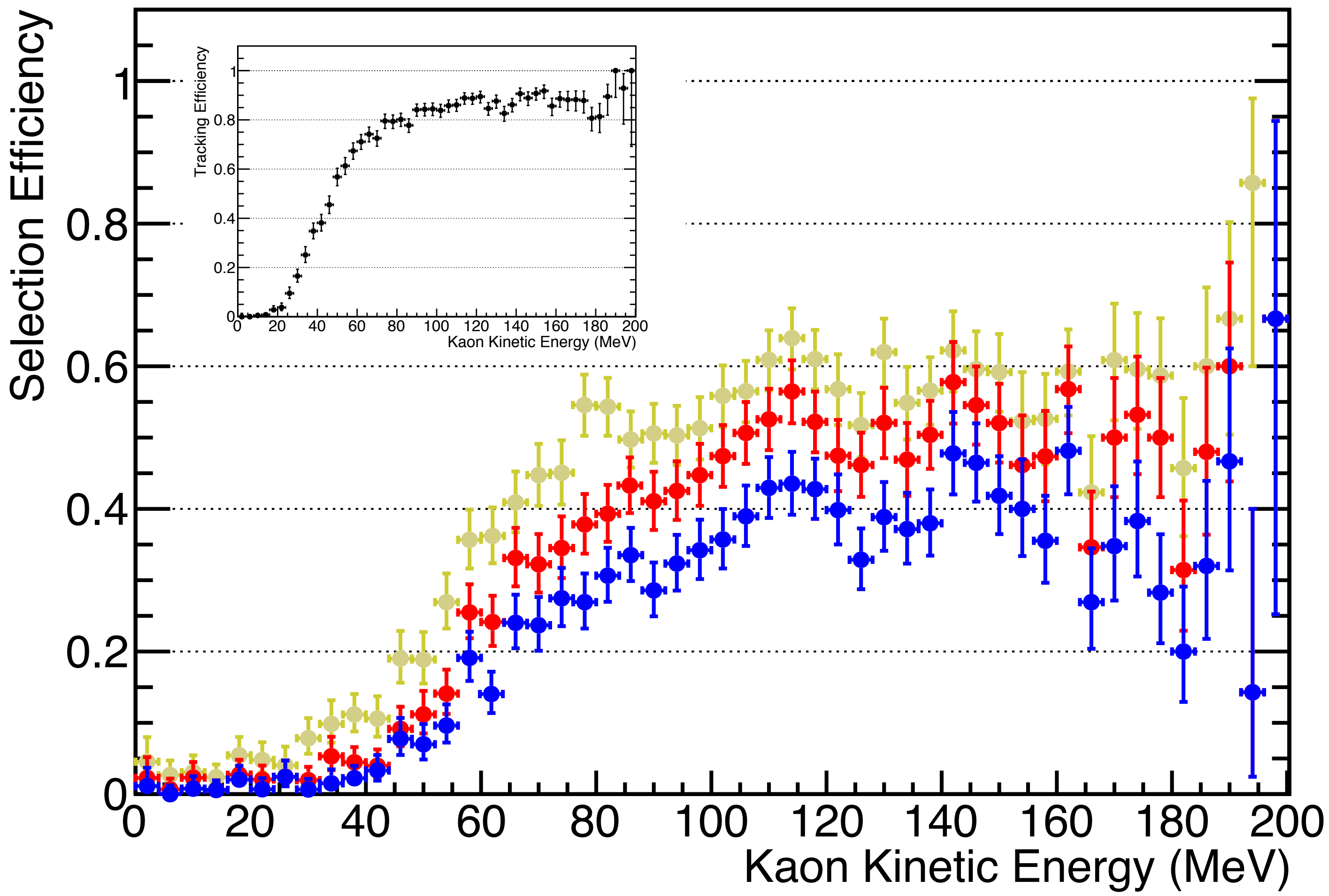
Overall tracking efficiency is 63.3%

How far can travel a 10 MeV kaon?

A few mm (1-2 wires)

Summary

Events selection K → μ



1) Golden events (Kaon ID and muon)
2) No shower-like
3) Kaon primary vertex

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